

has no effect! In Wang's 1979 modification, for the Americas, the effect of solar activity is included only if the midpoint of the path or half-path is $\geq 45^\circ$. Using these restrictions, the predicted field strengths for only 15 of these 36 paths would be affected by a change in solar activity.

The predicted field strengths for these 15 paths for two levels of solar activity, $R = 0$ and 100, for both CCIR methods and the Wang 1979 method (where applicable) are given in Table 3. For this comparison, the paths have been ordered according to the geomagnetic latitudes at the midpoint of each half-path (see Appendix A, Section 2.6). In Table 3, the second column indicates the value of b used to determine k_R for each half-path, and the next two columns give the geomagnetic latitude of the midpoint of each half-path. For the CCIR methods, the solar activity effect on the predicted field strengths is primarily dependent on path length. For the paths where b is either 1 or 4, the decrease in the predicted field strengths from solar minimum to solar maximum is 12 dB for path 1, 4797 km, and 16 dB for path 14, 6287 km. For the paths where there is a solar activity effect at only the midpoint of the half-path closest to the receiver, the decrease with solar activity is 3 dB for path 13, 6055 km, and 4.4 dB for path 27, 8644 km. However, in the Wang 1979 method, the predicted field strength is more dependent on geomagnetic latitude than path length. Because of this dependence, the predicted field strength decreases about 34 dB for path 1 from solar minimum to solar maximum; and as the geomagnetic latitude decreases, the predicted field strengths decrease with increasing solar activity but at a slower rate. In other methods, the effect of solar activity is implicit in the ionospheric loss models used; in these methods, the ionospheric loss is a function of geomagnetic latitude, path length, and frequency.

4.4 Comparison of Predicted Field Strengths with Measured Field Strengths

A comparison of measured field strengths with predicted field strengths for different levels of solar activity is shown in Table 4. The first column indicates the measured field strengths either provided to or compiled by the CCIR IWP 6/4 for 35 of the 36 paths. The measured field strengths for paths 6, 9, and 14 for $R = 20$ and for path 9 for $R = 100$ were extracted from CCIR (1937).

The paths have been grouped according to regions or geographical areas. In the first three groups, at least one of the terminals is located in Region 2. With the exception of paths 2, 3, 16, and 30, the measured field

Table 3. Comparison of Predicted Field Strengths for Different Solar Activity Levels (without sea gain) (F_0 in dB relative to 1 $\mu\text{V/m}$)

Path Number	b _{T,R}	Geom. Lat. Half-Path Midpoints	Path Length (km)	Frequency (kHz)	CCIR R=0	1974 R=100	Predicted Decrease	CCIR R=0	1978 R=100	Predicted Decrease	Wang R=0	1979 R=100	Predicted Decrease	
1	1,4	58.3	57.3	4797	977	-29.3	-41.3	12.0	-30.0	-42.0	12.0	-34.4	-68.5	34.1
4	1,4	56.7	52.5	5346	977	-26.8	-40.2	13.4	-26.9	-40.3	13.4	-30.6	-61.8	31.2
5	1,4	52.6	55.4	5426	1040	-26.6	-40.2	13.6	-26.6	-40.2	13.6	-29.1	-59.5	30.2
3	4,4	55.2	50.5	5298	1070	-22.7	-36.0	13.3	-22.7	-36.0	13.3	-24.4	-51.6	27.2
2	4,1	55.1	50.5	5272	1070	-22.2	-35.4	13.2	-22.1	-35.3	13.2	-23.8	-50.7	26.9
9	4,1	52.5	52.8	5839	860	-24.7	-39.3	14.6	-24.5	-39.1	14.6	-29.6	-59.1	29.5
8	4,1	52.4	52.5	5791	860	-23.7	-38.2	14.5	-23.5	-38.0	14.5	-28.4	-57.4	29.0
14	4,1	52.4	52.4	6287	860	-28.8	-44.5	15.7	-28.5	-44.3	15.8	-33.8	-65.0	31.2
6	1,4	51.5	52.1	5573	1040	-22.2	-36.1	13.9	-22.0	-35.9	13.9	-23.9	-50.2	26.3
12	1,4	51.0	50.6	5910	1040	-23.2	-38.0	14.8	-22.9	-37.7	14.8	-24.6	-50.0	25.4
30	0,1	35.7	50.2	9333	1157	-40.6	-45.2	4.6	-40.2	-44.8	4.6	-36.7	-55.7	19.0
16	0,1	32.6	45.8	7001	1310	-15.6	-19.1	3.5	-15.3	-18.8	3.5	-10.4	-18.5	8.1
17	0,1	-7.2	-26.2	7198	1580	-1.1	-4.7	3.6	-2.1	-1.4	3.5	NA	NA	---
27	0,1	10.4	-27.8	8644	770	-5.7	-10.1	4.4	-2.7	-7.0	4.3	NA	NA	---
13	0,1	-16.5	-29.4	6055	790	3.5	0.5	3.0	7.3	4.2	3.1	NA	NA	---

Table 4. Comparison of Measured Field Strengths with Predicted Field Strengths (F_0 in dB relative to 1 $\mu\text{V/m}$)

Path Number	Observation	R	Cairo Curves	Cairo Curves - L_p	CCIR 1974	CCIR 1978	WANG 1979
1. North America to Europe							
1	-14.1	100	-3.8		-41.3	-42.0	-68.5
2	2.6	0	-7.6		-18.8*	-17.8*	-20.4*
3	0.0	0	-7.7		-20.6*	-19.4*	-22.3*
4	-18.2	100	-8.0		-40.2	-40.3	-61.8
5	-13.5	100	-9.0		-40.2	-40.2	-59.5
6	-9.0	20	-9.8		-22.8*	-21.3*	-23.9*
6	-21.0	100	-9.8		-33.7*	-32.4*	-48.0*
8	-17.0	100	-11.5		-29.3*	-29.0*	-48.5*
9	-13.6	20	-11.7		-18.7*	-18.4*	-26.6*
9	-15.1	100	-11.7		-30.4*	-30.1*	-50.2*
12	-18.5	100	-12.1		-38.0	-37.7	-50.0
14	-19.5	20	-14.4		-22.4*	-22.1*	-30.6*
14	-31.0	100	-14.4		-35.0*	-34.7*	-55.5*
RMS Error			8.4		17.5	17.2	31.7
2. North America to S. America							
23	2.0	0	3.4	3.2	-6.6	-5.7	9.3
24	2.0	0	3.1	3.0	0.3*	1.7*	15.6*
25	-2.0	0	2.9	2.8	-0.9*	0.6*	15.0*
26	2.0	0	2.7	2.5	-8.1	-7.2	7.9
29	2.0	0	1.8	1.7	-12.8	-11.9	3.5
RMS Error			2.4	2.3	8.9	8.3	10.6
3. South and Central America to Europe							
16	0.0	0	6.6		-11.3*	-9.9*	-6.1*
30	-22.0	0	1.4		-31.6*	-31.1*	-27.7*
32	-9.9	100	-1.3	-2.1	-10.9*	-12.2*	9.1*
33	-11.5	100	-1.8	-2.5	-15.9*	-17.7*	3.8*
34	-13.5	100	-2.3	-3.1	-13.4*	-15.3*	7.4*
35	-7.5	100	-2.5	-3.3	-14.1*	-16.0*	6.8*
36	-17.0	100	-3.2	-4.1	-16.3*	-18.2*	5.6*
RMS Error			12.5	12.1	6.7	7.1	16.1
4. Europe, Africa, Mideast, & Asia							
7	18.3	0	9.6	7.9	17.8*	16.9*	
10	10.8	0	9.2	7.9	6.6*	4.9*	
15	5.5	0	7.0		9.3*	11.0*	
18	-1.1	0	5.2		-2.6	-2.2	
20	-7.5	0	4.6	3.6	-7.7*	-7.3*	
22	9.8	0	3.7		6.3*	7.6*	
28	-5.2	0	2.3	1.5	-11.8*	-9.1*	
RMS Error			7.2	7.2	3.6	3.6	
5. Mideast, Asia, & Pacific							
11	17.5	0	9.2	9.3	17.9*	15.4*	
13	-1.0	0	8.9	6.3	12.4*	16.4*	
17	3.0	0	6.2	3.8	7.5*	11.0*	
19	8.5	0	5.0		1.1	3.1	
21	0.7	0	4.6	-.9	5.0*	5.8*	
27	5.0	0	2.6		-5.7	-2.7	
31	-7.0	0	0.4	-3.3	5.7*	7.4*	
RMS Error			6.0	4.7	8.9	9.9	
TOTAL RMS Error			8.2	8.0	11.7	11.7	23.4

* Includes sea gain

strengths for these paths were used to derive the Cairo Curves. As would be expected, the Cairo predicted field strength is in closer agreement with the measured field strength for 15 of the 22 observations in these three groups.

As most of the observations for the first group of paths were made during a period of either low or high solar activity, the field strengths predicted by both the CCIR and the Wang 1979 methods include the effect of solar activity. The rms error between the observed and the Cairo predicted field strengths is significantly lower for the paths in group 1 than the rms error for the other three predictions. With the exception of path 14, the Cairo method predictions for the North Atlantic paths, group 1, consistently agree better with the observations than the predictions from the other methods. For the three paths, 6, 9, and 14, for which there are observations for low and high solar activity, there appears to be a solar cycle variation in the observations for only two of the paths, 6 and 14. For path 14, either of the CCIR field strength predictions for $R = 20$ and 100 , are in closer agreement with the observations than either the Cairo or Wang 1979 predictions. But the Cairo predictions, which do not include any solar activity effect, are closer to both observations for path 6 than the other three predictions. The only conclusion that can be made from a sample of this size is that the solar cycle effect cannot be eliminated completely as a contributing factor.

For the paths in group 2 for both CCIR methods, the solar activity factor b has been set to 0 for both half-path midpoints; and in the Wang 1979 method, the geomagnetic latitudes of the half-path midpoints are between 45°N and 45°S . Therefore, none of these predicted field strengths are affected by solar activity. All of the paths in this group were included in the measurement campaigns conducted by the IBU, and again the rms error for the Cairo predictions is significantly lower than the rms error for the other predictions. However, for the two paths that include G_s , the CCIR predictions are somewhat closer to the observations than the Cairo predictions.

The same solar activity restrictions for the paths in group 2 also apply to the paths in group 3; i.e., there is no variation with solar activity. For paths between Central-South America and Europe, the addition of sea gain in the CCIR predictions brings them into closer agreement with the observations than the Cairo predictions, with the exception of path 35. Note that the receiver for path 35 is Eindhoven, the same as for path 9, and the observations for path 9 were also inconsistent with other observations in group 1.

For the fourth group of paths from Europe to Africa, the Mideast, and Asia, the CCIR predictions, in general, are in better agreement with the observations than the Cairo predictions. Again, this is primarily due to the addition of sea gain.

The rms error for the Cairo predictions for the paths in group 5 tend to corroborate the recommendation of the 1975 Regional Administrative LF/MF Broadcasting Conference. In this limited sample, the Cairo field strength predictions with a correction for L_p for paths propagating in the west-east direction (13, 17, 21, and 31) are more compatible with the observations than the CCIR predictions. Although the addition of sea gain is applied to five of these seven paths in the CCIR methods, the CCIR field strength predictions are significantly better than the Cairo method predictions for only one of these paths (11).

When all groups are combined, the rms errors between observations and predictions given in Table 4 indicate that for this limited data sample the field strength predictions based on the Cairo Curves are in closer agreement with the observations than the other methods. However, the differences in the total rms errors are probably not statistically significant. In this analysis, the Cairo East-West Curve was used to predict MF field strengths for the North Atlantic paths in group 1. If the North-South Cairo Curve had been used to predict the field strength for the paths in this group, the corresponding rms error would have been about 26 dB. Similarly, if the variation with solar activity is eliminated in the CCIR 1974 and 1978 and the Wang 1979 predictions, the corresponding rms errors are 11.3, 10.9, and 13.0 dB, respectively. The rms error for the Cairo East-West Curve predictions is still the lowest, but the differences between the rms errors are probably not statistically significant.

There are 15 paths for which the CCIR predictions are better than the Cairo predictions, and sea gain was included in the predictions for all these paths with the exception of path 18. There is essentially no difference between the two CCIR prediction methods (see Table 3) except in the method for determining sea gain. The CCIR 1974 method for computing G_s is much simpler than the CCIR 1978 method, and based on this analysis, predicts the MF field strengths equally as well as the CCIR 1978 method.

The following three sections discuss several factors which, if explicitly taken into account in the prediction methods, might reduce some of the discrepancies between the observations and predictions.